

How to achieve the energy transition taking into account the efficiency of energy resources consumption

*Khrystyna Mykhailyshyn*¹, *Alla Polyanska*^{1,2*}, *Vladyslav Psyuk*³, and *Olena Antoniuk*⁴

¹Ivano-Frankivsk National Technical University of Oil and Gas, 15 Karpatska St., 78019 Ivano-Frankivsk, Ukraine

²AGH University of Krakow, Faculty of Management, 30 Mickiewiczza Ave., 30059 Krakow, Poland

³Dnipro University of Technology, 19 Yavornytskoho Ave., 49005 Dnipro, Ukraine

⁴Ukrainian State University of Science and Technologies, 4 Nauky Ave., 49005 Dnipro, Ukraine

Abstract. The study explores the transformation of energy resource consumption centered on energy efficiency within the global energy transition framework. The growing global energy demand, driven by industrialization, urbanization, and rising living standards, has led to increased fossil fuel consumption. This, in turn, contributes to higher greenhouse gas emissions, global warming, and other adverse environmental impacts. The study emphasizes the efforts of developed nations to curb these emissions, particularly by expanding renewable energy use, and notes the declining share of coal and other fossil fuels in national energy balances. The Energy Transition Index (ETI) is introduced as a measure of countries' progress in advancing the energy transition, including efforts to enhance energy efficiency and mitigate environmental harm. The study also highlights Ukraine's challenges in energy supply due to military conflict and infrastructure damage, underscoring the critical role of energy efficiency in rebuilding the country's energy system and securing its energy future. Energy efficiency is identified as a key strategy for reducing dependence on fossil fuels, decreasing energy imports, and bolstering the economy's resilience to external pressures.

1 Introduction

Global energy demand is rising swiftly due to several factors, including population growth, industrialization, and changes in lifestyle. As living standards improve, energy consumption increases, driven by factors like the use of private vehicles and a wider range of household appliances. A significant contributor to this rising demand is the economic development of countries, which requires ever-growing energy supplies. This rapid energy consumption, particularly from fossil fuels, has a persistent negative effect on the environment, including a continuous annual rise in global temperatures (Fig. 1).

* Corresponding author: polyanska@agh.edu

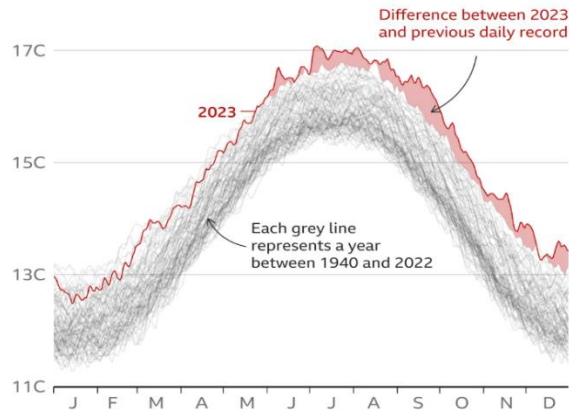


Fig. 1. Daily global average air temperature 1940 – 2023 [1].

Emissions of greenhouse gases are widely recognized as the main factor of global warming and its harmful consequences worldwide [2]. However, in recent years, countries with developed economies are on the path to reducing greenhouse gas emissions, particularly in the energy sector due to a gradual reduction in the use of coal for electricity generation, an increase in the share of renewable energy sources, as well as the use of other types of fuel with a lower intensity of greenhouse gas emissions (Fig. 2).

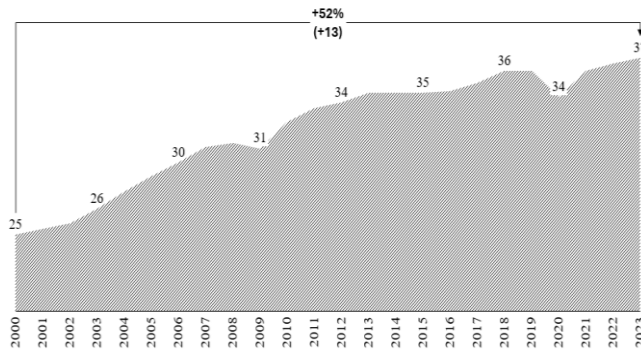


Fig. 2. Energy-related CO₂ emissions, billion tons [3].

For example, the coefficient of carbon dioxide emissions when burning 1MWh of natural gas is about 202 kg of CO₂, but when burning 1MWh of coal, the coefficient reaches more than 403 kg, which is almost twice as much [4].

2 Prerequisites of the energy transition

The dynamics of energy supply from coal in countries with developed economies in the period from 1905 to 2023 is characterized by significant fluctuations due to various political, economic, and environmental events (Fig. 3).

Thus, at the beginning of the 20th century, the energy supply from coal grew due to a significant increase in demand, in particular for military needs during World War I and World War II. [5, 6] Classically, during world crises, in particular the Great Depression, the consumption of basic energy resources decreased significantly due to a decrease in industrial activity. Modern examples that similarly affected the reduction of coal-based energy supply

are the global financial crisis of 2007-2009, as well as the economic crisis during the active phase of the COVID-19 pandemic in 2020 [7 – 9].

During the 50s and 70s of the 20th century, energy supply from coal in developed countries remained the main source for ensuring economic growth, and the OPEC crisis in the early 70s, which occurred due to the introduction of an embargo on oil products by the Arab countries, led to significant interruptions in the supply of oil, which, in turn, forced the US and Europe to reconsider their dependence on oil from the Middle East, in particular at the expense of coal, as well as increasing the energy consumption efficiency of energy resources [10]. The Chernobyl disaster in 1986, which resulted in massive radioactive contamination, had not only a significant environmental impact, but also an impact on energy policy in developed countries. Many countries have revised their plans to build new nuclear reactors or have decided to phase out the use of nuclear energy. The accident at the Chernobyl nuclear power plant caused significant concern about the safety of nuclear power, and also caused anti-nuclear sentiment among the governments of many countries, which increased the demand for coal in the energy supply, as a more reliable and proven source of energy, but this trend was short-term [11, 12]. An important step in the direction of reducing coal consumption, which is one of the main sources of CO₂ emissions, was the Kyoto Protocol [13], which was adopted in 1997 as an international agreement aimed at reducing greenhouse gas emissions. Its main purpose is to limit the emission limits of greenhouse gases into the atmosphere.

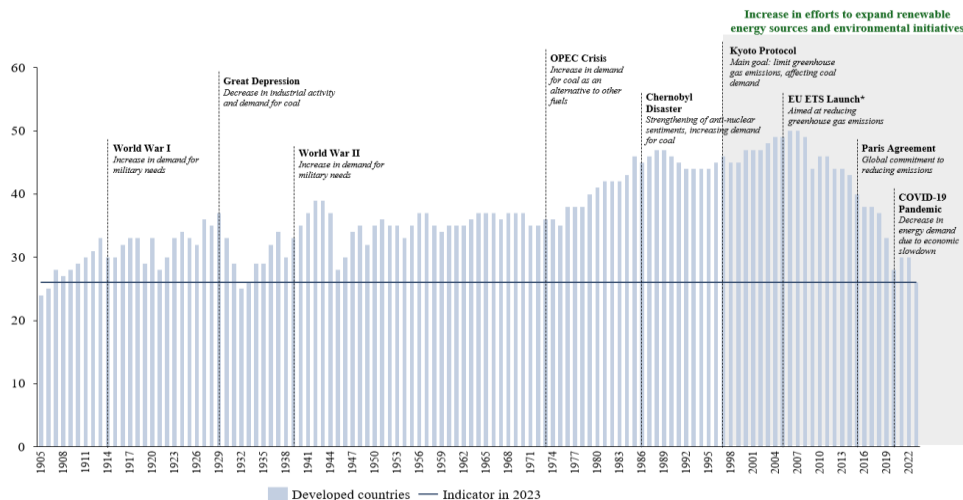


Fig. 3. Dynamics of energy supply from coal in countries with developed economies (Source: Compiled on the base of Data – IEA [14]; Events – compiled by the authors based on [5 – 7, 10, 11, 13 – 17]).

The countries that signed the protocol undertook to reduce emissions of carbon dioxide and other greenhouse gases. However, the decrease in energy supply from coal was observed only after the launch of the EU ETS (European Union Emissions Trading System) in 2005 as the world's first and largest greenhouse gas emissions trading system. It allows companies to buy and sell emission permits, incentivizing them to reduce their emissions. This measure contributed to the transition to more environmentally friendly technologies, as the use of coal became financially less profitable due to the high cost of emission permits [15]. As a result of efforts to reduce the negative impact on the environment, over the last decades, developed countries have actively invested in the development of renewable energy sources, such as wind and solar energy. Governments in many countries have introduced incentives for the development of these technologies, including subsidies, tax breaks and financing programs.

This led to a significant reduction in the cost of energy production from renewable sources and an increase in their share in the energy balance [16]. The Paris Agreement, signed in 2015, was another important step in the fight against climate change. It has set ambitious goals for reducing greenhouse gas emissions, limiting global warming, and increasing the share of renewable energy sources. The agreement encouraged countries to develop national plans for the decarbonization of the economy and the transition to environmentally friendly technologies [17].

Taking into account the indicated trends in energy consumption led to research in the field of energy transition, justification of opportunities and ways of implementing the necessary changes [18]. In particular, one of the issues related to the energy transition is the rational use of energy resources, the research of which examines various ways of achieving energy efficiency [19]. In addition, the study of the prerequisites of the energy transition is accompanied by the study of the company's readiness for changes [20].

The growing demand for energy combined with the need to reduce greenhouse gas emissions is an urgent challenge, so countries are actively implementing various target plans to reduce emissions, transition to clean energy sources, and reduce energy consumption. However, despite these efforts, global temperatures continue to rise, as do the total energy-related greenhouse gases [21]. This requires a deeper study of the issue of energy transition, constant monitoring of the decisions made results and study of the countries experience that have succeeded in the energy transition, and justification of measures on the way to transforming energy consumption. In turn, the aim of this article is to explore how to achieve a successful energy transition while maximizing the efficiency of energy resource consumption. It examines approaches, technologies, and policies that facilitate this transition and highlights best practices for optimizing energy use to ensure performance and readiness of necessary changes.

3 Data and methods

Various data sources were used to analyze the transformation concept of energy resource consumption based on energy efficiency in the context of the energy transition. Among the main sources is information from the International Monetary Fund, the World Economic Forum, the European Commission, the International Energy Agency and others, which included information about the amount of CO₂ emissions, the average annual air temperature in the world, the dynamics of energy transition index estimates at the global level and Ukraine, etc. These data helps to understand global trends in energy consumption, energy transition and energy efficiency levels.

Analytical reports and studies prepared by scientific institutions, consulting companies and government bodies have also become an important source of information. These documents contained an analysis of various policies impact and global events on the concept of energy resource consumption from the perspective of energy efficiency in the context of the energy transition.

The study used several methods for data analysis, including statistical analysis to identify major trends in the changing concept of energy consumption. The comparative analysis helped to assess the pace of the energy transition at the global level with the results of Ukraine, as well as various energy efficiency practices, as well as actions aimed at achieving the goals of the energy transition.

In order to determine the direction of achieving energy transition due to energy efficiency, we suggest considering the Energy Transition Index (ETI), which is evaluated on the basis of two main components: assessment of system efficiency and assessment of readiness for transition (Fig. 4).

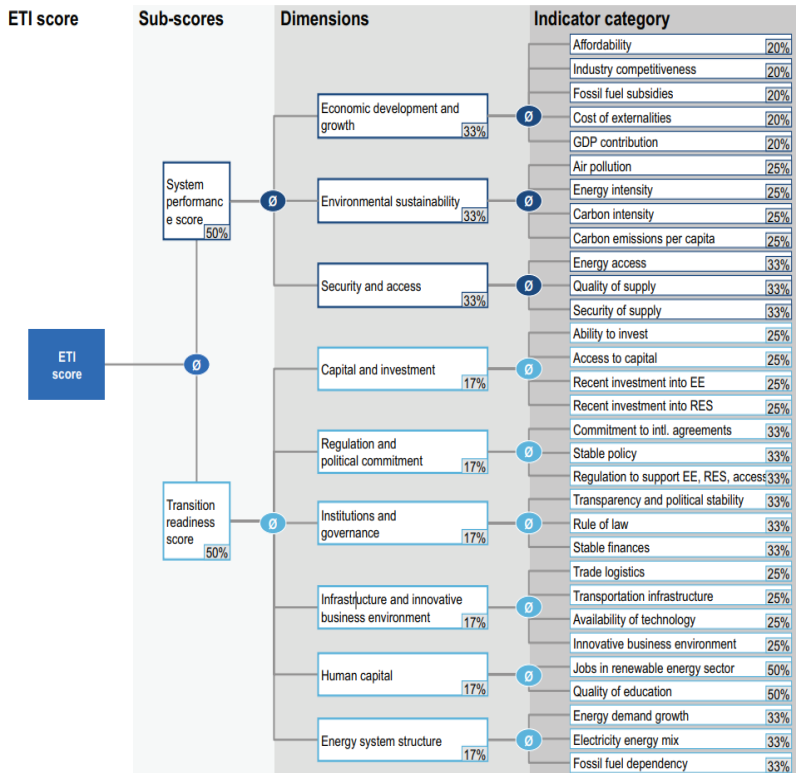


Fig. 4. Energy Transition Index indicators [22].

The indicators considered within the scope of this method determine the state of the energy transition and readiness for changes. By analyzing the dynamics of indicators of the state and readiness of the energy transition, it is possible to make decisions on solutions that are required to achieve better performance and due to which we can increase readiness for changes, developing and supplementing the results of previous studies [19].

4 Results and discussion

Any energy resources, including wind, sun, natural gas, etc., are raw materials that are indispensable for the successful economic growth and development of countries, while the approach applied to the consumption of these raw materials is a central aspect of energy efficiency issues in the energy transition.

Currently, Ukraine, in particular the energy system, is at one of the most difficult stages. Russia continues to destroy Ukraine's energy facilities. During the first wave of large-scale missile attacks, the Russians damaged almost half of the power system. As a result of the second wave of attacks, which began in March 2024 and continues to this day (there have already been six massive attacks), about 90% of the electricity generation of the Ukrainian company DTEK was damaged or destroyed (as of mid-July 2024) [23]. According to the Kyiv School of Economics, which, together with the Ministry of Community Development, Territories and Infrastructure, the Ministry of Health, the Ministry of Economy and in cooperation with other relevant ministries and the National Bank of Ukraine, assesses the damage caused to the infrastructure of Ukraine during the full-scale invasion, damages and losses of the energy sector of Ukraine exceeded \$56 billion. USA (as of May 2024) [24].

According to the IMF, it is expected that the energy deficit in Ukraine will persist during 2024 – 2025, in particular, in 2024, the average energy deficit is expected at the level of 10% (up to 30% during peak hours of consumption). However, this assessment includes the repair of part of RES assets, increased energy imports from the EU, as well as the installation of new smaller gas-fired power generation facilities (up to 1 GW), while not taking into account further missile attacks on Ukraine's energy infrastructure, which may further destabilize energy system [25].

In the conditions of a shortage of energy resources and the impossibility of independent provision of one's own energy needs in Ukraine, the issue of energy efficiency becomes extremely important. Moreover, in the context of global warming and the growth of greenhouse gas emissions, the need to increase energy efficiency, taking into account the latest technologies and energy transition strategies, is additionally formed. Thus, the ongoing war and continued attacks on the energy system highlight the critical need to rebuild energy infrastructure, but it is important to rebuild it based on new approaches focused on energy efficiency and achieving energy transition goals. Energy efficiency must also be considered from the perspective of an additional sources of energy, as it contributes to reducing the consumption of both traditional and renewable energy sources. Thus, energy efficiency is an energy resource possessed by all countries without exception, which is based on the transformation of the concept of the energy resources consumption and meets the conditions of the energy transition [26]. Therefore, for Ukraine, which is currently facing serious challenges due to military actions and the destruction of the energy infrastructure, energy efficiency can become one of the key tools for recovery and development, and the integration of the energy transition into the reconstruction process that will allow creating a new, more efficient energy system that will meet needs of the modern world [27].

An important tool for assessing the progress of countries in the energy transition is the Energy Transition Index (ETI), which was developed by the World Economic Forum team. This index takes into account a variety of indicators such as access to renewable energy sources, energy efficiency, greenhouse gas emissions, energy security and policy efforts to support the energy transition, etc. The purpose of calculating the energy transition index is to provide an objective and comparative assessment of the readiness and countries ability to implement the energy transition [22, 25]. This index identifies the strengths and weaknesses of the energy policy of individual countries, which, in its turn, helps governments, international organizations and investors to make informed decisions about investments and to provide appropriate reforms in the energy sector. The index also plays an important role in the global context of climate change combating. By assessing progress in the implementation of renewable energy sources and reduction of greenhouse gas emissions, considered index helps to track the implementation of international commitments such as the Paris Agreement. This contributes to increased transparency and accountability of governments in their efforts to reduce the impact of the energy sector on the environment.

In the context of Ukraine, the energy transition index have a particular importance. Given the challenges associated with military actions and the need to restore the energy infrastructure, the results of the index can become a valuable guide for planning and implementing energy reforms. Using the data of the index, Ukraine will be able to integrate the principles of energy efficiency into the process of reconstruction and modernization of the energy system with greater benefit to satisfy their own needs, taken significant steps to comply with the conception of sustainable development.

The global dynamics of the Energy Transition Index (ETI) shows an increasing trend from 2015 to 2024, despite recorded decrease in 2023. The global value of the Energy Transition Index (ETI) reached its maximum value in 2021, which indicates improvements in the energy sector, including an increase in the share of renewable energy sources, increased energy efficiency, improved energy legislation, etc., but the progress is uneven. High-income countries are making more progress in environmental sustainability than other regions of the world. The

list of leading countries according to the energy transition index remained quite stable during the period under study, including Sweden, Norway, Denmark, Switzerland, France and others, although each of them has its own unique path of energy transition (Fig. 5).

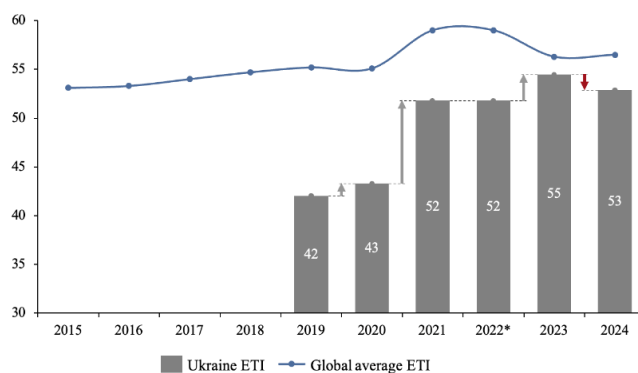


Fig. 5. Dynamics of the energy transition index (ETI), % (Compiled by the authors based on [22, 28-33]; *the energy transition index based on the results of 2022 has not been published, the graph shows the value of 2021).

On the other hand, the dynamics of Ukraine’s energy transition index shows significant growth in the period from 2019 to 2023, with a slight decline in 2024. Moreover, the index results indicate that the pace of energy transition in Ukraine is significantly higher compared to the global average ETI growth, although Ukraine’s ETI score is still lower than the global average. The growth of Ukraine’s ETI results was due to the improvement of legislation and regulation, which contributed to the attraction of investments in renewable energy, as well as the implementation of effective state support mechanisms [34], the introduction of state programs and initiatives, active policy in the field of energy efficiency and energy audit [35], in particular approval of the energy efficiency action plan for the period until 2030 [36], etc. Therefore, according to the results of the energy transition index assessment, Ukraine has significant potential for further energy transition and energy efficiency improvement. However, the ongoing war presents significant obstacles to these plans, including the destruction of infrastructure and disruption of energy supplies. Despite these difficulties, Ukrainian companies such as DTEK continue to invest in renewable energy, in particular in solar power plants and other types of RES. For example, DTEK implements projects in the field of solar energy even during wartime, demonstrating sustainability and commitment to the development of green energy in the country [37]. In addition, Ukraine is actively considering the possibility of exporting biomethane to the European Union, which could become a significant source of income for the country and help reduce the EU’s dependence on traditional fuels. Currently, the Ukrainian authorities are actively implementing the relevant legislation, in particular, the Ukrainian Parliament passed a law that allows the export of biomethane to Europe [38]. According to experts, Ukraine can produce more than 20 billion cubic meters in the future of biomethane per year. This is a very high potential that will make it an important player on the European energy market [39]. Some Ukrainian companies have already started biomethane production projects, which is an important step in the direction of sustainable energy development. A striking example is the Ukrainian agro-industrial company MHP, which successfully operates two biogas complexes [40].

Maintaining stable progress in the energy transition is a challenge for all countries, including Ukraine since a decrease in the ETI result was recorded in 2024. The Energy Transition Index (ETI) is assessed based on two main components: a system performance assessment and a transition readiness assessment. Each of these components is divided into

several subcategories and measured by different indicators. In particular, the decline of the energy transition index of Ukraine in 2024 is more related to the deterioration of the assessment of readiness for the energy transition, and to a lesser extent to the deterioration of the assessment of system efficiency, which are the main components of the ETI with the same weight of influence (Fig. 6). The main reason for the decrease in Ukraine's ETI rating is primarily the Russian invasion of Ukraine, which continues to cause significant social and economic losses, which affects the energy infrastructure and the ability to implement energy reforms, and constant military actions create high uncertainty, which complicates the planning and implementation of long-term energy projects. In addition, part of Ukraine's energy infrastructure is destroyed, which requires significant funds and time for restoration, which is complicated by risks related to timely receipt of external financing, which is necessary to support the economy and the energy sector [41].

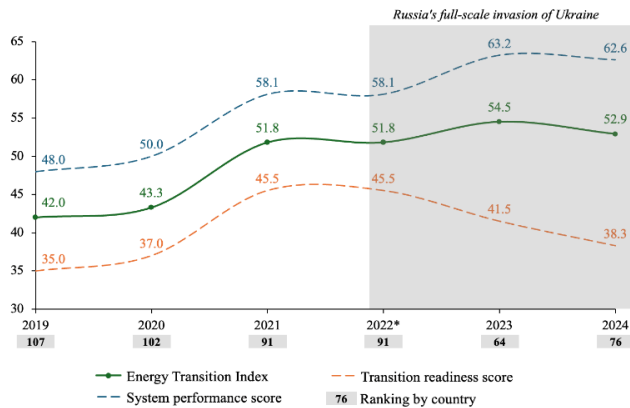


Fig. 6. Dynamics of the energy transition index of Ukraine (ETI) and its main indicators, % (Compiled by the authors based on [22, 28 – 33]; *the energy transition index based on the results of 2022 has not been published, the graph shows the value of 2021).

Energy efficiency is a key element of the energy transition, as it helps reduce energy consumption, reduce greenhouse gas emissions, and reduce dependence on fossil fuels. Implementing energy-efficient technologies and practices allows for less energy usability to achieve the same results, which also means that less energy needs to be produced, transported and consumed. In turn, energy efficiency helps to reduce the amount of greenhouse gas emissions that are generated during energy production and consumption, and also helps to reduce the demand for fossil fuels, which promotes the transition to renewable energy sources and reduces dependence on energy imports. Therefore, the Energy Transition Index takes into account various indicators of energy efficiency, such as energy intensity of the economy, growth in energy demand, energy mix, etc.

Energy efficiency management can be carried out at five main levels, including the global level (international organizations, all countries), macro level (countries), meso level (regions), micro level (enterprises, organizations), and individual (specific person) [19]. Given this, the Energy Transition Index is an indicator that assesses global and individual country achievements, corresponding to the global and macro levels, and therefore, despite the value of the Energy Transition Index (ETI) and its impact at the macro and global levels, currently there is no corresponding index for evaluating the energy transition at lower levels, for example for the micro level, which would evaluate the progress of companies according to the main criteria of the energy transition. Since the success of a country's energy transition is based on specific actions and achievements at lower levels, it is appropriate to adapt the energy transition index for micro-level assessment.

5 Conclusions

Therefore, the global demand for energy resources continues to grow, which poses serious environmental challenges to humanity, related to the increase in greenhouse gas emissions and global warming. Developed countries are actively working to reduce the use of fossil fuels and transition to renewable energy sources, which is an important step in the fight against climate change. In 2023, developed countries have achieved a reduction in energy supply from coal to the level at the beginning of the last century. International agreements and emissions trading systems, as well as ongoing assessments of countries using the Energy Transition Index, play an important role in stimulating these processes. However, despite significant achievements, the pace of energy transition is still quite slow, and the efforts of countries are unevenly distributed.

Ukraine, facing challenges caused by military actions and the destruction of energy infrastructure, has a unique opportunity to reshape its energy system, focusing on energy efficiency and renewable sources. The result of the Energy Transition Index (ETI) for Ukraine in 2024 reached about 53%, compared to 42% in 2019, which shows positive changes, but further efforts are needed to achieve better indicators. Despite these results, the result of 2024 is lower compared to the value of 2023, which is primarily caused by the military invasion of Russia and its consequences. The global average value of ETI in 2019 was around 55%, and in 2024 it increased to 57%, which also indicates positive dynamics, but it is clear that the growth rate of global results is much lower than in Ukraine. Thus, Ukraine has significant potential for further energy transition and energy efficiency improvements, but the ongoing war creates significant obstacles to these plans, including destruction of infrastructure and disruption of energy supplies. Special attention should be paid to the development of policies and measures aimed at increasing energy efficiency and supporting renewable energy.

The Energy Transition Index is responsible for assessing countries' energy transition efforts, but despite its value, there is currently a need to adapt the ETI for a company-level assessment that would assess companies' progress against key energy transition criteria, including energy efficiency criteria. This is important because the success of the country's energy transition is based on specific measures and achievements of enterprises (organizations), and therefore has a direct impact on the results of the index at the country level. Energy efficiency must also be considered from the perspective of an additional source of energy, as it contributes to reducing the consumption of both traditional and renewable energy sources. Thus, energy efficiency is an energy resource possessed by all countries without exception, which is based on the transformation of the concept of the use of energy resources and meets the conditions of the energy transition.

References

1. BBC. (2024). *2023 confirmed as world's hottest year on record*. Retrieved from <https://www.bbc.com/news/science-environment-67861954>
2. U.S. Environmental Protection Agency. (2024). *Basics of Climate Change*. Retrieved from <https://www.epa.gov/climatechange-science/basics-climate-change>
3. IEA. (2024). *Total increase in energy-related CO₂ emissions, 1900-2023*. Retrieved from <https://www.iea.org/data-and-statistics/charts/total-increase-in-energy-related-co2-emissions-1900-2023>
4. Our World in Data. (2023). *Carbon dioxide emissions factors*. Retrieved from <https://ourworldindata.org/grapher/carbon-dioxide-emissions-factor>
5. Notz, W. (1918). The World's Coal Situation During the War: I. *Journal of Political Economy*, 26(6), 567-611. <https://doi.org/10.1086/253111>
6. Mierzejewski, A. (1988). The Collapse of the German War Economy, 1944-1945: Allied Air Power

- and the German National Railway. Retrieved from <https://www.semanticscholar.org/paper/The-Collapse-of-the-German-War-Economy%2C-1944-1945%3A-Mierzejewski/56554cba041b1b6acab6f043b1149c69503f4544>
7. Kehoe, T.J., & Prescott, E.C. (2002). Great depressions of the 20th century. *Review of Economic Dynamics*, 5(1), 1-18. <https://doi.org/10.1006/redy.2001.0151>
 8. World Bank Groupe. (2022). *Chapter 1. The economic impacts of the COVID-19 crisis*. Retrieved from <https://www.worldbank.org/en/publication/wdr2022/brief/chapter-1-introduction-the-economic-impacts-of-the-covid-19-crisis>
 9. Economics Observatory. (2023). *Why did the global financial crisis of 2007-09 happen?* Retrieved from <https://www.economicsobservatory.com/why-did-the-global-financial-crisis-of-2007-09-happen>
 10. Graf, R. (2012). Making Use of the “Oil Weapon”: Western Industrialized Countries and Arab Petropolitics in 1973-1974. *Diplomatic History*, 36(1), 185-208. <http://dx.doi.org/10.1111/j.1467-7709.2011.01014.x>
 11. Naoum, S., & Spyropoulos, V. (2021). The nuclear accident at Chernobyl: Immediate and further consequences. *Romanian Journal of Military Medicine*, 124(2), 184-190. <http://dx.doi.org/10.55453/rjmm.2021.124.2.9>
 12. Gazeta.ua. (2024). *The Chornobyl disaster slowed down the development of nuclear power for twenty years*. Retrieved from <https://gazeta.ua/articles/opinions-journal/cornobilska-katastrofa-spovilnila-rozvitok-atomnoyi-energetiki-na-dvadcyat-rokiv/1177917>
 13. Maamoun, N. (2019) The Kyoto protocol: Empirical evidence of a hidden success. *Journal of Environmental Economics and Management*, (95), 227-256. <https://doi.org/10.1016/j.jeem.2019.04.001>
 14. IEA. (2024). *Energy supply from coal in advanced economies, 1905-2023*. Retrieved from <https://www.iea.org/data-and-statistics/charts/energy-supply-from-coal-in-advanced-economies-1905-2023>
 15. European Commission. What is the EU ETS? Retrieved from https://climate.ec.europa.eu/eu-action/eu-emissions-trading-system-eu-ets/what-eu-ets_en
 16. The Det Norske Veritas Group. (2023). *Energy Transition Outlook. The rise of renewables*. Retrieved from <https://www.dnv.com/energy-transition-outlook/rise-of-renewables/>
 17. United Nations. *The Paris Agreement*. Retrieved from <https://www.un.org/en/climatechange/paris-agreement>
 18. Polyanska, A., Pazynich, Y., Mykhailyshyn, K., & Buketov, V. (2023). Energy transition: the future of energy on the base of smart specialization. *Naukovyi Visnyk Natsionalnoho Hirnychoho Universytetu*, (4), 89-95. <https://doi.org/10.33271/nvngu/2023-4/089>
 19. Polyanska, A., Pazynich, Y., Mykhailyshyn, K., Babets, D., & Toš, P. (2024). Aspects of energy efficiency management for rational energy resource utilization. *Rudarsko-Geološko-Naftni Zbornik*, 39(3), 13-26. <https://doi.org/10.17794/rgn.2024.3.2>
 20. Zapukhliak, I., Zaiachuk, Y., Polyanska, A., & Kinash, I. (2019). Applying fuzzy logic to assessment of enterprise readiness for changes. *Management Science Letters*, (9), 2277-2290. <https://doi.org/10.5267/j.msl.2019.7.026>
 21. Yang, D., Zhao, J., Suhail, S. A., Ahmad, W., Kamiński, P., Dyczko, A., Salmi, A., & Mohamed, A. (2022). Investigating the Ultrasonic Pulse Velocity of Concrete Containing Waste Marble Dust and Its Estimation Using Artificial Intelligence. *Materials*, 15(12), 4311. <https://doi.org/10.3390/ma15124311>
 22. World Economic Forum. (2024). *Fostering Effective Energy Transition 2024*. Retrieved from <https://www.weforum.org/publications/fostering-effective-energy-transition-2024/>
 23. *DTEK lost 90% of its generation due to shelling, but plans to return most of it by October*. (2024). Retrieved from <https://www.epravda.com.ua/news/2024/07/23/>
 24. Kyiv School of Economics. (2024). *Damages and losses to Ukraine’s energy sector due to Russia’s full-scale invasion exceeded \$56 billion – KSE Institute estimate as of May 2024*. Retrieved from <https://kse.ua/ua/about-the-school/news/zbitki-ta-vtrati-energetichnogo-sektoru-ukrayini->

- [vnaslidok-povnomasshtabnogo-vtorgnennyya-rosiyi-perevishhili-56-mlrd-otsinka-kse-institute-stanom-na-traven-2024-roku/](#)
25. International Monetary Fund. (2024). *Ukraine: Fourth Review of the Extended Arrangement under the Extended Fund Facility, Request for Modifications of a Performance Criterion, and Financing Assurances Review-Press Release; Staff Report; and Statement by the Executive Director for Ukraine*. Retrieved from <https://www.imf.org/en/Publications/CR/Issues/2024/06/28/Ukraine-Fourth-Review-of-the-Extended-Arrangement-under-the-Extended-Fund-Facility-Request-551207>
 26. Skrypnyk, D.M. (2021). *Organizational and economic mechanism of forming an energy efficient model of national economy development*. PhD Thesis. Sumy, Ukraine: Sumy National Agrarian University. Retrieved from https://science.snau.edu.ua/wp-content/uploads/2021/12/Diss_SkrypnykD.pdf
 27. Polianska, A., & Mykhailyshyn, Kh. (2023). Peredumovy enerhetychnoho perekhodu vitchyznianskykh pidpriemstv v umovakh pislivoiennoho vidnovlennia. In *Mizhnarodnyy naukovyy forum "Naftohazova enerhetyka"* (pp. 275-276). Ivano-Frankivsk, Ukraine: Ivano-Frankivskyyi natsionalnyi tekhnichnyi universytet nafty i hazu.
 28. World Economic Forum. (2018). *Fostering Effective Energy Transition 2018*. Retrieved from <https://www.weforum.org/publications/fostering-effective-energy-transition/>
 29. World Economic Forum. (2023). *Fostering Effective Energy Transition 2023*. Retrieved from <https://www.weforum.org/publications/fostering-effective-energy-transition-2023/>
 30. World Economic Forum. (2022). *Fostering Effective Energy Transition 2022*. Retrieved from <https://www.weforum.org/publications/fostering-effective-energy-transition-2022/>
 31. World Economic Forum. (2021). *Fostering Effective Energy Transition 2021*. Retrieved from <https://www.weforum.org/publications/fostering-effective-energy-transition-2021/>
 32. World Economic Forum. (2020). *Energy Transition Index 2020: from crisis to rebound*. Retrieved from <https://www.weforum.org/publications/fostering-effective-energy-transition-2020/>
 33. World Economic Forum. (2019). *Fostering Effective Energy Transition 2019*. Retrieved from <https://www.weforum.org/publications/fostering-effective-energy-transition-2019/>
 34. Razumkov Centre. (2022). *Ukraine's renewable energy sector before, during and after the war*. Retrieved from <https://razumkov.org.ua/statti/sekto-vidnovlyuvanoyi-energetyky-ukrayiny-do-pid-chas-ta-pislyva-viyny>
 35. State Agency for Energy Efficiency and Energy Saving of Ukraine. *Energy efficiency*. Retrieved from <https://sae.gov.ua/uk/content/energy-efficiency>
 36. Legislation of Ukraine. (2023). *On the National Energy Efficiency Action Plan for the period up to 2030*. Retrieved from <https://zakon.rada.gov.ua/laws/show/1803-2021-%D1%80#Text>
 37. DTEK. (2024). *Last year, 43 solar power plants were connected to the capital's power grid by DTEK Kyiv Power Grids*. Retrieved from: <https://www.dtek-kem.com.ua/ua/news/43-sonyachni-elektrostantsiji-pid-yednav-minulogo-roku-do-energostemi-stolici-dtek-kijivski-elektromerezhi>
 38. Ministry of Agrarian Policy and Food of Ukraine. (2024). *Parliament passes law allowing export of biomethane to the EU*. Retrieved from https://minagro.gov.ua/news/parlament-ukhvalyv-zakon-iakyi-dozvoliaie-eksportuvaty-biometan-v-ies?_cf_chl_tk=Ei2MibGnZ0RAn7Hb42eYDgd49l7WIFPmc_JZkFKmYtw-1722194444-0.0.1.1-4030
 39. Naftogaz of Ukraine. (2024). *Oleksiy Chernyshov: Ukraine has one of the largest potentials in Europe for biomethane production*. Retrieved from <https://www.naftogaz.com/news/ukraine-has-one-of-the-largest-potentials-in-europe-for-the-production-of-biomethane>
 40. MHP. *Biogas complexes of MHP*. Retrieved from <https://mhp.com.ua/uk/pro-kompaniiu/biogaz-ta-mhp-eko-enerdzi>
 41. International Monetary Fund. (2024). *IMF Executive Board Completes the Third Review of the Extended Fund Facility Arrangement for Ukraine*. Retrieved from <https://www.imf.org/en/News/Articles/2024/03/21/pr2496-ukraine-imf-executive-board-completes-third-review-eff>